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Core Automated Maintenance System (CAMS) at the Flightline: Nellis AFB Structured Study Test Report

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FOR THE COMMANDER

//Signed//

MARK M. HOFFMAN
Deputy Chief
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13. ABSTRACT *(Maximum 200 words)*
One data collection system the US Air Force uses to capture all aircraft maintenance actions is the Core Automated Maintenance System (CAMS). Infrastructure and hardware are in place at Nellis AFB for CAMS to be used via a mobile device on the flightline. The mobile system at Nellis AFB is referred to as the Nellis AFB CAMS at the Flightline system. This document describes a usability test conducted by the Air Force Research Laboratory and the University of Dayton Research Institute at Nellis AFB: The test assessed the Nellis AFB CAMS at the Flightline system accessing CAMS via two different modes. These modes of maintenance documentation were: 1) a portable laptop accessing CAMS via wireless frequency and 2) the desktop device accessing CAMS via wired network. The conditions tested included: 1) opening work orders, 2) listing open work orders, and 3) closing work orders in both the stationary CAMS condition and in the mobile CAMS condition. This study focused on the differences and similarities between the stationary CAMS and mobile CAMS access methods, as well as the usability of each. Significant time savings are realized by use of the mobile system when required travel time is included as part of the overall task; however, when time required for the additional logon required in the mobile condition is included in the analysis, no significant time savings are observed for the mobile system as compared to the stationary method. The additional sign-on time is identified as the key factor precluding significant time savings when using the mobile system.

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PREFACE

The research documented in this technical report for the CAMS at the Flightline: Nellis Structured Study Test Report program sponsored by the Air Force Research Laboratory, Human Effectiveness Directorate, Logistics Readiness Branch (AFRL/HESR), Wright-Patterson Air Force Base, OH. The University of Dayton Research Institute performed the work under Delivery Order #06 of the Technology for Readiness and Sustainment (TRS) contract F33615-99-D-6001. Maj. Matthew W. Goddard and Capt. Brian Tidball (AFRL/HESR) are the program managers for the effort.

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1 Executive Summary

One tool the US Air Force uses to capture all aircraft maintenance actions is the Core Automated Maintenance System (CAMS), a Maintenance Data Collection System (MDC). When the term "maintenance documentation" is used in this document, it refers to MDC or CAMS documentation, not to be confused with aircraft forms (781) documentation, a related but separate issue. CAMS was updated across the Air Force in 2002 with the release of the new CAMS Graphical User Interface (GUI); thus, the term "CAMS," as used in this document, is assumed to refer to the GUI version unless otherwise noted.

Infrastructure and hardware are in place at Nellis AFB, NV for CAMS to be used via a mobile device on the flightline. The purpose of this infrastructure and hardware is for aircraft maintainers to document aircraft maintenance actions at the point of maintenance. (The term "point of maintenance" refers simply to the location of the maintainer at the time and place aircraft maintenance is completed.) The mobile system at Nellis AFB is referred to in this report as the Nellis AFB CAMS at the Flightline system, or simply as the mobile CAMS system. The Nellis AFB CAMS at the Flightline system was evaluated by an AFRL team for usability per direction from HQ USAF/ILMM. The AFRL team included military members from the AFRL Human Effectiveness Directorate's Logistics Readiness Branch, and civilian members from the University of Dayton Research Institute (UDRI) and NCI Corporation. The team tested and observed eight subjects using CAMS at the Flightline.

Objective measurements (i.e., time) were recorded while observing maintainers documenting simulated aircraft maintenance using both stationary CAMS terminals and the mobile system. Results indicate that when the technician's travel time to and from the aircraft is considered as part of the overall task, significant time savings are realized by use of the mobile system; however, when the additional time required to sign-on to the mobile system is included in the analysis, no significant time savings are observed for the mobile system as compared to the stationary method. The central recommendation from these objective measurements is that the mobile system sign-on time be reduced through streamlining of the sign-on process (e.g., combining the multiple logins required in the mobile condition) or through more use of a more effective wireless network. The sign-on time is the key identified factor precluding significant time savings when using the mobile system.

Subjective data was also collected via user feedback and experimenter observations. Two key subjective findings are summarized as follows: First, the sometimes lengthy response of the CAMS system (primarily when accessing drop-down menus) lends to frustration in both the stationary and mobile conditions. This frustration is intensified with the additional delays in accessing these menus across the wireless network using the mobile device. Second, participants preferred the stationary CAMS system to mobile CAMS because of the additional logon required in the mobile condition, the higher perceived reliability of the stationary system, the preference for the traditional mouse over the stylus, and simply because of the heat stress conditions of the Nellis AFB Flightline.

In consideration of both the objective and subjective data, the recommendations from this study are that both the mobile (CAMS at the Flightline) and stationary CAMS systems be available to maintenance technicians, and that mobile CAMS sign-on time be reduced.

2 Introduction

This document describes the usability test conducted by the Air Force Research Laboratory and the University of Dayton Research Institute to assess user performance with the CAMS at the Flightline system for mobile maintenance data collection. This exploration of CAMS at the Flightline has sprung from a broader Air Force initiative to apply technology to improve the maintainer's capabilities at the point of maintenance. Traditionally, the maintainer works a task at an aircraft, ventures indoors to access a CAMS terminal and database, populates necessary data and receives feedback, and returns to the flightline to complete the documentation at the aircraft. The advent of remote devices providing access to the CAMS database has permitted maintenance documentation to occur entirely while the technician is at the aircraft, or at the point of maintenance. This test consisted of: 1) observations of task performance in two conditions accessing one application of CAMS, and 2) feedback questionnaires about the usability of both the baseline and test devices. The two performance conditions were based upon the two modes of operation (i.e., stationary and mobile use) for access to the CAMS database. The stationary CAMS condition, representative of the traditional maintenance documentation process, served as the baseline in this study. The mobile CAMS condition reflects one possible application of the point of maintenance concept, wherein maintainers accessed the same GUI as in the stationary condition, but accessed it via a portable laptop connected to a wireless network.

The CAMS GUI is the newest release of CAMS, which updates the previous version of CAMS, the CAMS Green Screen interface. Given that the CAMS GUI had only recently been released, participants in this study were also asked their opinion of the CAMS GUI in comparison to the CAMS Green Screen interface. The responses are included in the results section.

The purpose of this evaluation was to assess the Nellis AFB CAMS at the Flightline system accessing CAMS via wireless frequency against the desktop device accessing CAMS via wired network for maintenance documentation (i.e., opening work orders, listing open work orders, and closing work orders). Both of these methods are currently in use at Nellis, the site of this test. The CAMS at the Flightline device used was the Itronix GoBook MAX with the CAMS GUI; the current CAMS system consisted of a standard desktop computer using the CAMS GUI interface. Both systems were connected to live training databases. The design allowed for U.S. Air Force personnel to use the devices in a flightline-type setting to perform the necessary maintenance documentation tasks.

The conditions tested included opening work orders, listing open work orders, and closing work orders in both the stationary CAMS condition and the mobile CAMS condition. This study focused on the differences and similarities between the stationary CAMS and mobile CAMS access methods, as well as the usability of each.

2.1 Objectives

This usability test was designed to address the following usability issues:

- For the MDC tasks of opening jobs, listing open jobs and closing jobs on the flightline, how does mode of operation (mobile device connected with CAMS, or stationary device connected with CAMS) affect performance?

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- Which mode of operation do users prefer?
- Is the access to information on the mobile device acceptable?

2.2   Test Methodology

Usability test methods applied in the current evaluation are based on principles outlined by Dumas and Redish (1993). In accordance with these usability testing methods, design of the study included three steps (see Figure 1). First, the major usability issues were identified. These included concerns about the general use (e.g., the ability of the device to operate as a mobile access device). From these general concerns, specific concerns were identified (see the objectives above). Finally, methods for collecting information relevant to these concerns were identified. Methods included multiple metrics for each concern (e.g.. collecting time measurements for completion of specific tasks, and collecting subjective information).
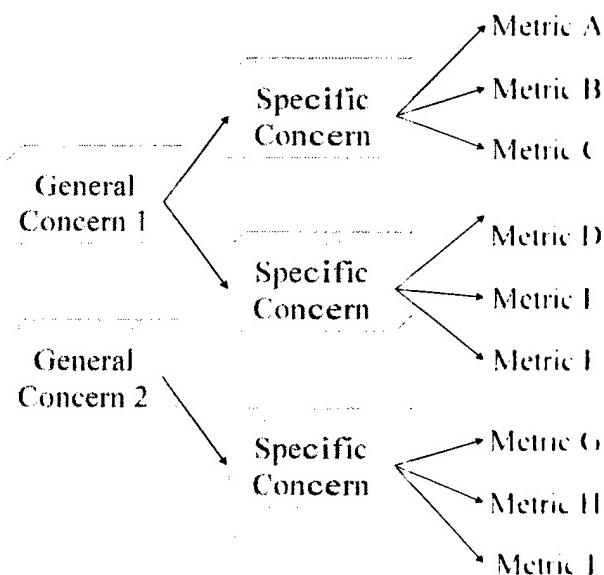
Figure 1. Usability testing methods (Dumas and Redish, 1993).

During the course of the study, time data measurements were recorded as subjects completed each of the tasks in the stationary and mobile CAMS conditions. These time measurements permitted an objective comparison of maintenance documentation tasks in these conditions.

In addition to the time data recorded in this study, participants responded to questions pertaining to the identified usability concerns. For this data, the analysis leverages the strength of triangulating the information gathered for each specific concern. For example, the specific concern dealing with how mode of operation affects performance included use of three metrics: subject ratings, experimenter observations of the participant while using the device, and specific participant comments (both written and verbalized, during the test and in post-test discussions). Performance times further validate this subjective analysis. Using triangulation, each metric is applied to confirm findings of another metric so that if all three metrics identify the same issue, the strength of usability concern is increased. Similarly, as multiple participants identify the same usability problem, the usability problem is revealed. Methods used to analyze data are fully addressed in the Results section of this document.

In identifying usability concerns, research indicates that the number of participants need not be as high as tests aimed at determining significance (e.g., Analysis of Variance (ANOVAs), or tests of correlation). Virzi (1992) identifies that 4 to 5 subjects identify 80% of the usability problems with a system, and that additional subjects are less likely to identify any new problems. The current test included 8 subjects, and therefore should be considered to be of relatively high strength in identifying usability concerns for the devices tested. When considering the objective data, 8 subjects alone may not be of sufficient power; this may increase the likelihood of a Type II error (i.e., not finding significance when there is actually a difference). However, when the objective data is viewed with the subjective feedback, the combined data should provide a good overall picture of the usability of the system.

3　Method

3.1　Participants and Facility

Eight U.S. Air Force personnel at Nellis AFB served as participants. These individuals were assigned to the 57th Aircraft Maintenance Squadron (AMXS). Participants were drawn from the A-10, F-16 and F-15 weapon systems. All participants were either crew chiefs or specialists. Testing was conducted at the 57th AMXS, Nellis AFB, NV.

3.2　Time and Schedule

The testing was conducted from 19 May through 22 May 2003. Pre-testing occurred on the first day of testing. Pre-testing consisted of assuring that appropriate software was loaded on the hardware devices, and re-evaluating all scenarios to verify that the same types of manipulations were required across devices. Subjects were scheduled on a non-interference basis; that is, scheduling was arranged based solely on availability, so as not to interfere with subjects' regular work. Each subject was scheduled for 2 hours; no one required more than this amount of time. Following the pre-test activity, testing occurred on the remaining three days. Testing on all three days lasted for most of the day (morning and afternoon).

3.3　Test Equipment Requirements

Hardware used in the test included the items listed below.

1. Itronix GoBook MAX (750 MHz Intel Pentium III processor with 256 KB L2 cache 512 MB SDRAM and transflective display) ruggedized laptop with CAMS access
2. Extra batteries for Itronix GoBook MAX
3. Battery charger for Itronix GoBook MAX
4. Standard CAMS (1.8 GHz Intel Pentium 4 processor) workstation configured with CAMS access

3.4　Data Collection Equipment

Data collection instruments included the following items.

1. One (1) video tape recorder with batteries
2. Blank videocassette tapes (14)
3. Clipboards (5)
4. Package of pens (1)
5. Digital camera (1)

3.5　Data Collection Packet

Data collection packets included a variety of forms. Each subject completed all forms prior to the end of the test.

1. Checklist
2. In-briefing
3. Consent form

4. Pre-test questionnaires
5. Post-condition questionnaires
6. Post-test questionnaires

3.6 Data Collection Team

The data collection team consisted of three individuals: 1) one experimenter/videographer, 2) a subject matter expert, and 3) a study coordinator. The experimenter conducted the in-briefing and out-briefing sessions and administered the questionnaires. The experimenter also operated a video camera in order to record participants' actions during the study. The subject matter expert provided the majority of the interaction with test participants. The study coordinator was responsible for assuring that scheduling was completed for all participants, and that all hardware and software were available for the test.

3.7 Pre-Test Requirements

Several activities needed to be completed prior to beginning this test; most of these activities required coordination with the hosting facility.

1. Experimenters required time to view the CAMS software. This software was loaded on the Itronix GoBook MAX laptop prior to this test. Experimenters thoroughly reviewed this during the pre-test.
2. Experimenters required time to review the features of the Itronix GoBook MAX so that they would be familiar with the device prior to the test. This was accomplished during the pre-testing day.
3. Experimenters created and finalized scenarios for the subjects to use during the test. Scenarios were developed several weeks prior to the test and finalized on the pre-testing day.
4. Experimenters were granted clearance to take photos at Nellis AFB. Videotaped data and digital photos were captured during the test.
5. Experimenters required use of an aircraft parking spot on the flightline for testing. The selected parking spot was as close as possible to the 57th AMXS maintenance dispatch location.

3.8 Test Procedure

Test participants were provided an in-briefing in a conference room setting. This in-briefing provided an overview of the purpose of the test. At this time they also completed the consent form, and completed the pre-test questionnaire. Each participant started with the baseline stationary CAMS condition. In this condition, participants used a CAMS terminal to complete the appropriate documentation for an aircraft inspection. First, participants initiated Windows and CAMS logons on the stationary CAMS terminal, used the stationary CAMS terminal to open a job based upon appropriate data, and then logged out of CAMS. Participants then logged into CAMS again, inspected and printed an electronic list of all open jobs, and logged out of CAMS. Finally, participants logged into CAMS, closed the job using the stationary CAMS terminal, and logged out of CAMS a final time. At this point, the individual logged off of the workstation. Time measurements were recorded for the three documentation tasks participants completed in the baseline condition. After the participants performed the

documentation (i.e., open job, list open jobs, and close job), they were asked to fill out a post-condition questionnaire.

Following the completion of the baseline condition, each subject used the laptop with CAMS in the mobile condition to complete the same documentation: participants opened a job, listed open jobs and closed a job on the mobile system. Prior to beginning the mobile condition, each participant received training on the mobile device. Once trained on the device, individuals were provided the option of initiating Windows and network logons at the support section (where they picked up the device), or waiting until they were at the aircraft. In the mobile CAMS condition, participants again were required to logon to Windows, as they had in the stationary condition. However, the mobile CAMS condition required an additional logon step, wherein participants were required to logon to the wireless network. Once logged in to Windows and the network, participants could logon to the CAMS database. Either before or after this logon, participants walked as quickly as possible to the aircraft parking spot that was closest to the 57th AMXS maintenance dispatch location. At the aircraft parking spot, participants used the mobile CAMS device to open a job for inspection, and then logged out of CAMS. Participants then logged into CAMS again, retrieved and reviewed an electronic list of all open jobs, completed the steps to print the list (but did not actually print the list), and logged out of CAMS. Finally, participants logged in to CAMS, closed the job in the CAMS system, and logged out of CAMS. Once the job was successfully closed participants initiated the Windows shut down and network logoff, and walked back to the starting area. In the mobile condition, times were recorded for each of the three tasks completed on the laptop. Following this process participants were asked to fill out a post-condition questionnaire and a post-test questionnaire.

The CAMS entries completed in this study reflect documentation of the maintenance that maintainers complete along the flightline. The test plan originally included an order parts task, but was replaced by the list/print open jobs task. This was a creative substitution due to the fact that maintainers at Nellis do not order parts; rather, the ordering parts task is a supply responsibility. It is commonplace, however, for a maintainer to retrieve a list of open jobs affecting an aircraft, and print out that list for use on the flightline. Thus, the list/print open jobs task was substituted for the order parts task in this test. The actual printing of the list was simulated due to the fact that the system was not configured with printers that would be familiar to the participants. Participants completed the necessary steps on the laptop to arrive at the print options screen, but selected the Cancel option instead of the Print option at this point.

Travel times were also collected for inclusion with the analysis of the stationary task. For the convenience of the participants, these travel times were collected in conjunction with the mobile CAMS condition; that is, participants were timed when they walked from the 57th AMXS to the nearest aircraft parking space before they completed the mobile task, and then were timed when they walked from that parking space back into the building after having completed the mobile CAMS condition. The average of these times was then determined for each participant for inclusion in specific time data comparisons. The mobile CAMS allowed for real-time remote data interaction, and no travel time was required to input and receive data from the CAMS database; individual travel times were recorded to better document the activity that would in fact be required for completion of the stationary CAMS condition.

4   Results

Analysis of the data collected during this study included participants' subjective evaluations of both devices across a series of characteristics, as well as a direct comparison of actual task time required to complete specific maintenance documentation activities. These analyses are detailed in the following sections, and include both subjective and objective results. It is important to note that a triangulation method was used in the analysis of subjective findings for each device. Triangulation was implemented as defined in the following paragraphs.

Ratings for both devices were gathered for each item in the questionnaire (e.g., for each question), and mean ratings and standard deviations were then calculated on each item for that device. Ratings could range from 1 to 5 (one was positive and five was negative).

A priori, criteria were set that 1) any item with an average rating of ≥ 3 indicated a usability problem, and 2) any item where the total of the average rating plus standard deviation was ≥ 3 indicated a *potential* usability problem.

Once this initial analysis was complete, user ratings were plotted on a cluster graph for items that indicated usability problems or potential usability problems. User comments and observer notes were then analyzed and collapsed to assist in the definition and clarification of the problem or potential problem. That is, user comments and observer notes that related specifically to the item were added to the analysis to assist in further definition of the problem or potential problem.

Participants completed various maintenance documentation tasks (i.e., the open job, list open jobs, and close job documentation tasks) associated with aircraft maintenance in two different conditions: 1) the stationary CAMS condition, which represented a maintainer's typical documentation experience, and 2) the mobile CAMS condition, which utilized a wireless connected laptop device to allow remote completion of the above maintenance documentation tasks. Completion times for these tasks and subjective feedback are discussed in the analysis.

Finally, a comparison was made between the relevant completion times for the various maintenance documentation activities. Three maintenance documentation tasks were completed in both the stationary and mobile CAMS conditions. Thus, the times associated with opening a job, listing all open jobs, and closing a job were compared across the two conditions.

4.1   Subjective Results

Participants completed the maintenance documentation activities (i.e., open job, list open jobs, and close job) on the stationary CAMS desktop as a baseline. Participants entered data typical for their specialty to complete the documentation tasks successfully. For the mobile CAMS condition, participants completed these same documentation activities at the aircraft using a laptop.

After completing the maintenance documentation tasks in each condition, participants rated each device across a series of elements using a 5-point scale, where one was positive and five was negative. Participants rated the acceptability of each device for such tasks as: logging on to the network, logging on to CAMS, opening a job, listing open jobs, printing, closing a job, using the drop-down menus, and navigating. Additionally, participants rated the acceptability of

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the wireless connectivity of the mobile CAMS device, and comparatively rated their frustration levels when using each system.

In all categories, the average ratings in both the stationary CAMS condition and the mobile CAMS condition were in the acceptable range; that is the average rating in each category was not greater than or equal to 3. Based on this rating, it is concluded that there were no demonstrated usability problems in either condition.

In the stationary CAMS condition, the average rating plus one standard deviation remained within the acceptable range for all categories except the acceptability of the drop-down menus. This indicates that the only *potential* usability problem revealed in the stationary CAMS condition for this study related to the acceptability of the drop-down menus (Figure 2).

Stationary CAMS

Network Logon

CAMS Logon

Opening a job

Listing open jobs

Printing

Closing a job

| Potential Problem |

Drop down menus

Navigation

Completely Acceptable   Reasonably Acceptable   Neither Acceptable Nor Unacceptable   Reasonably Unacceptable   Completely Unacceptable
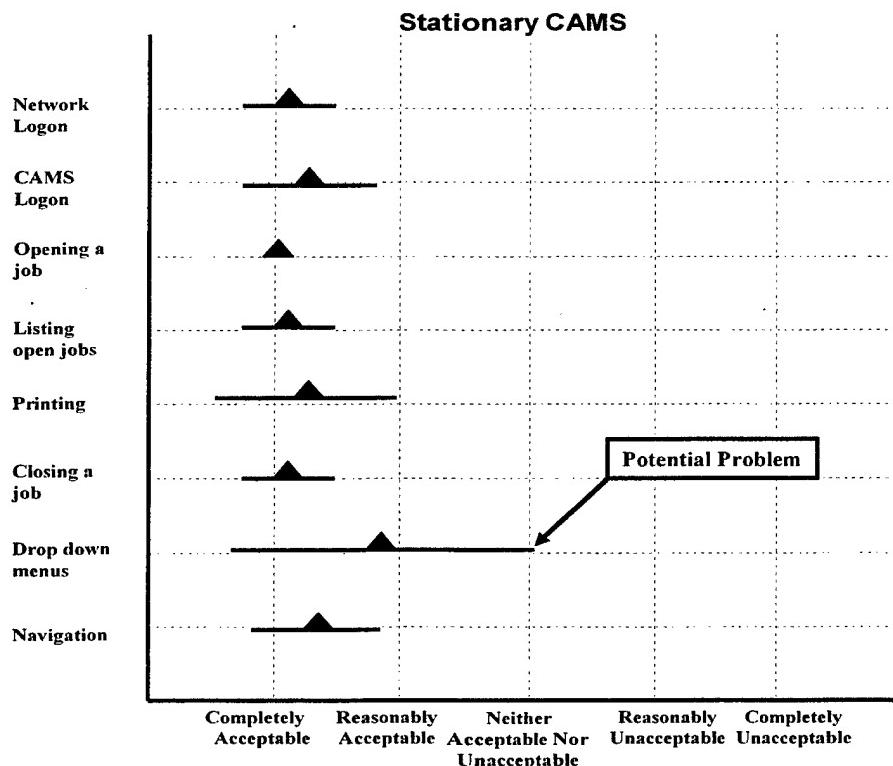
Figure 2. Means and Deviations - acceptability ratings for the stationary CAMS condition.

In the mobile CAMS condition, the calculation of the average rating plus standard deviation revealed four potential problems; these problems were related to the acceptability of the network logon, printing from the mobile CAMS, drop-down menus, and wireless connectivity (Figure 3).
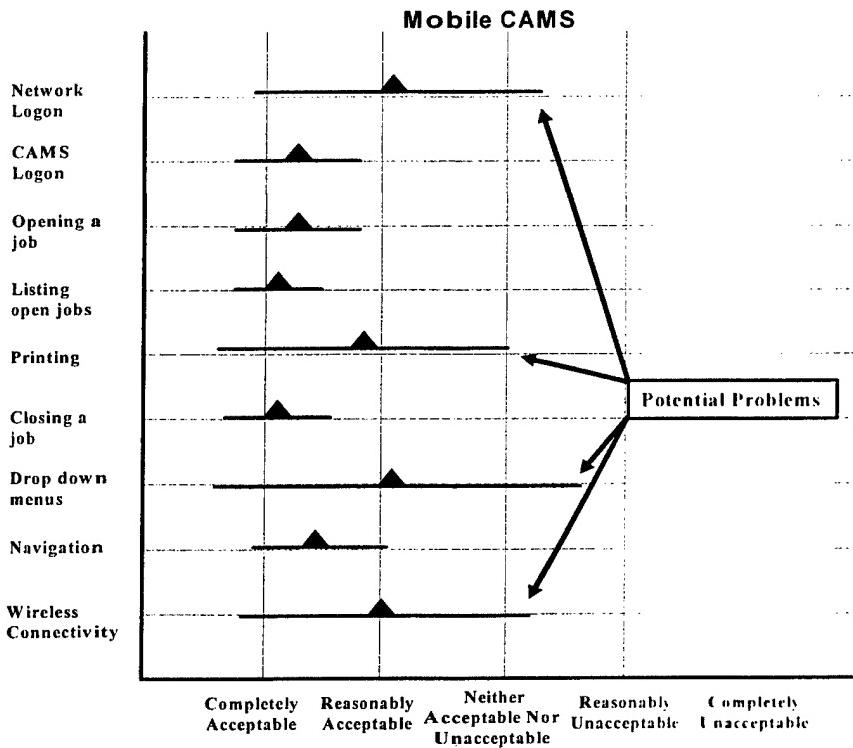
Figure 3. Means and Deviations - acceptability ratings for the mobile CAMS condition.

In both the stationary CAMS and mobile CAMS conditions, individual ratings identified the acceptability of drop-down menus as a potential problem (Figure 4). Additionally, in the mobile CAMS condition, acceptability of network logon, printing and wireless connectivity were defined as potential problems. Individual ratings for these three usability categories are illustrated in Figures 5, 6, & 7.
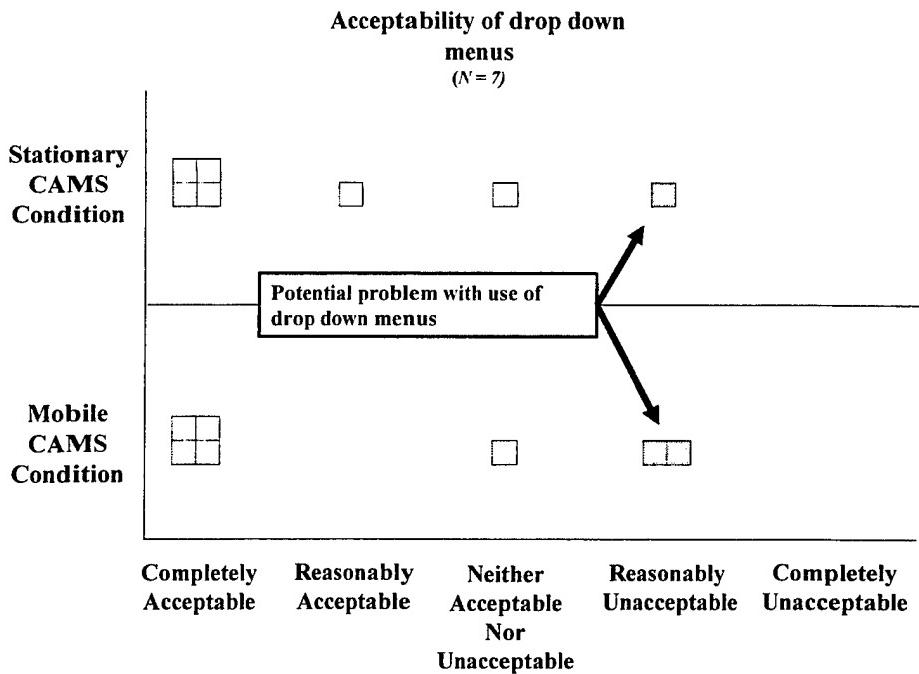
Figure 4. Individual ratings for acceptability of drop-down menus in stationary and mobile CAMS conditions.

Individual ratings for acceptability of drop-down menus in both the stationary and mobile CAMS conditions indicated potential problems. Seven participants provided ratings for this item. In the stationary CAMS condition, 5 participants provided ratings in the acceptable range: 4 participants rated the drop-down menus Completely Acceptable, and 1 participant rated the drop-down menus Reasonably Acceptable. However, 2 participants provided ratings in the unacceptable range: 1 participant rated the drop-down menus as Neither Acceptable Nor Unacceptable, and 1 participant rated the drop-down menus as Reasonably Unacceptable.

In the mobile CAMS condition, 4 participants provided ratings in the acceptable range for this item, rating the drop-down menus Completely Acceptable. Three participants provided ratings in the unacceptable range: 1 participant rated drop-down menus in the mobile CAMS condition Neither Acceptable Nor Unacceptable, and 2 participants rated the drop-down menus Reasonably Unacceptable.

Participants provided some general comments about the drop-down menus: 3 participants pointed out that the drop-down menus were useful when entering such items as "aircraft equipment P/N's and serial #'s." Participants also provided some constructive criticism that included: "I like the idea of the pop down windows if they can get them faster and more reliable"; "the only problem was the lagging drop-down menu." The drop-down menus used in the CAMS GUI are unlike those that appear in standard Windows applications: the CAMS GUI drop-downs consist of windows that pop-up (when the drop-down is selected) and are populated with the relevant data. Participants then select an item from this list, which populates the associated field, and then close the pop-up window.

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The data population in these pop-up windows can take some time. When an individual selects the drop-down list, that request sends a query to the CAMS server where the system searches for all values that should be within that list, and then returns the necessary values to populate the list. As this list can contain a tremendous number of items, this query-and-return process can be lengthy. Furthermore, added time associated with network traffic, as in the mobile CAMS condition, could further exacerbate the wait. Experimenters noted that, in both conditions, participants waited approximately 45 to 60 seconds for some drop-down menus to populate.

Furthermore, the drop-down menus are a new addition to CAMS. Maintainers are accustomed to referring to maintenance books to determine the values that are now served by the drop-down menus, and may in fact recall many values (e.g., the necessary work unit code) from memory. Thus, while the current method for populating the drop-down menus is not expeditious, these menus do allow maintainers access to necessary data from the simplicity of a laptop. Maintainers have the option to cancel the request of any drop-down menu that responds too slowly (and experimenters noted that several individuals did so in this study). At this point, they can either type in the required information from memory or go find the required paper reference.
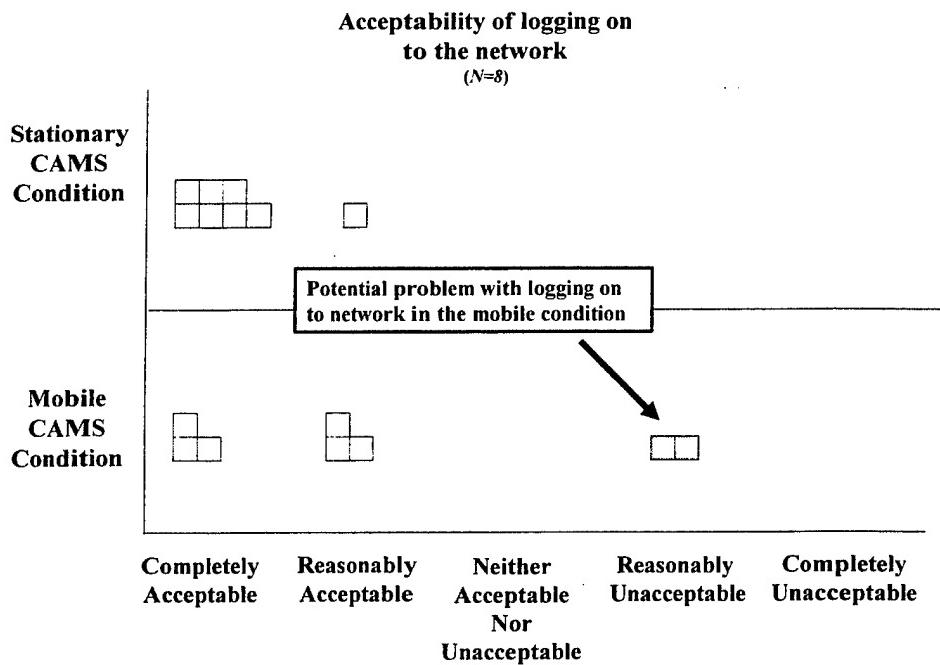
Figure 5. Ratings for acceptability of network logon in stationary and mobile CAMS conditions.

Individual ratings for acceptability of network logon indicated potential problems in the mobile CAMS condition. Eight participants provided ratings for this item. In the stationary CAMS condition, all ratings were in the acceptable range; however, in the mobile CAMS condition, six ratings were in the acceptable range – 3 participants provided ratings of Completely Acceptable, and 3 provided ratings of Reasonably Acceptable – but 2 participants provided ratings of Reasonably Unacceptable, indicating a potential problem with this item. Participants did not provide comments regarding their network logon ratings.

Experimenters noted that several participants were unfamiliar with the network logon process, and that this lack of familiarity created problems for the users. Not only was there an additional logon step in the mobile CAMS condition – after participants signed in to Windows, they were still required to logon to the network before logging into CAMS – but this logon was different from the Windows logon, and was often not easily recalled by individuals who had not recently used this login and password. Thus, the presence of an additional step in the process was likely exacerbated by login recall difficulties. Windows and network logins can, in fact, be synched for user convenience, but were not aligned for this study. In the stationary CAMS condition, the act of logging into Windows logged the user onto the network, as well. Additionally, the system was already on, which is the normal state of these computers. These factors reduced any wait time required of the user and are likely reflected in the more positive perception of the stationary CAMS condition for this usability item.

Acceptability of printing
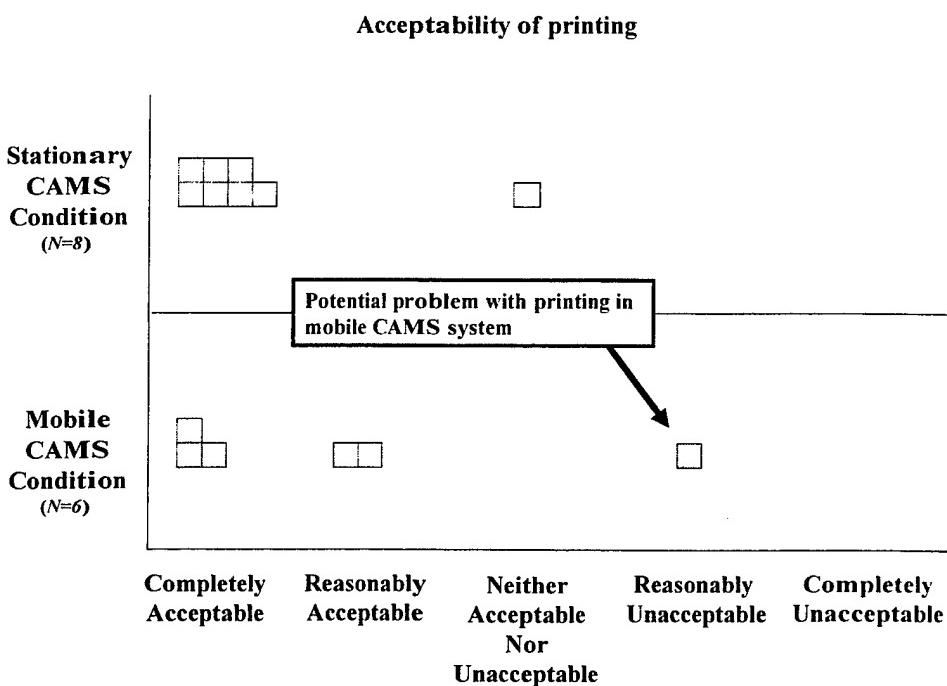
*Figure 6.* Ratings for acceptability of printing in stationary and mobile CAMS conditions.

Individual ratings for the acceptability of printing indicated potential problems in the mobile CAMS condition. Six of eight participants provided ratings for this item in the mobile condition. In the stationary CAMS condition, all ratings were in the acceptable range; however, in the mobile CAMS condition, one of the six ratings was in the unacceptable range, where 1 participant rated printing in the mobile condition Reasonably Unacceptable. In the list and print open jobs task, participants in the mobile CAMS condition only completed the steps necessary to initiate the printing task, and then cancelled out of the print window without actually printing. Two participants chose not to rate the printing process in the mobile CAMS condition because they did not actually print the list of open jobs.

Experimenters noted that the simulated print task created some confusion for the participants. The laptop was configured according to the requirements of the support section

where the hardware was checked out; that is, the laptop was configured with printers from the 57th AMXS maintenance dispatch location. Thus, when participants arrived at the printer selection window, all of the printers were unfamiliar. This may have suggested that the printing process with the mobile device would be unlike printing from the desktop. Naturally, if individuals were using these devices on a regular basis, the printer options would be defaulted based upon the assigned unit of the individual. In addition, maintainers generally print lists of open jobs from the stationary desktop CAMS system in order to have that list accessible at the aircraft. As this list of open jobs is available on the mobile device, the printed list may become far less necessary.

Acceptability of wireless connectivity
(N=8)

Potential problem with wireless connectivity in mobile condition

Mobile CAMS Condition

| Completely Acceptable | Reasonably Acceptable | Neither Acceptable Nor Unacceptable | Reasonably Unacceptable | Completely Unacceptable |
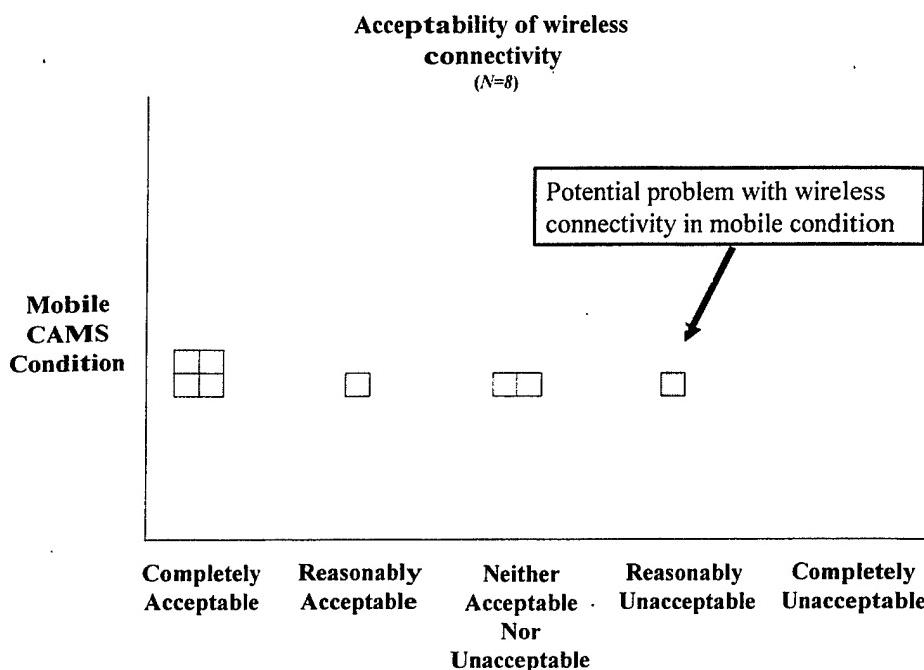
Figure 7. Ratings for acceptability of wireless connectivity in mobile CAMS condition.

Individual ratings of acceptability of the wireless connectivity in the mobile CAMS condition indicated a potential problem. Due to the hard-wired capabilities of the stationary CAMS condition, wireless connectivity was not rated in that condition. In the mobile condition, 5 participants provided ratings in the acceptable range, and 3 participants rated the wireless connectivity in the unacceptable range: 2 participants considered the wireless connectivity Neither Acceptable Nor Unacceptable, and 1 rated wireless connectivity Reasonably Unacceptable. Participant comments indicated that there continues to be some difficulty with wireless connectivity. For example, one participant pointed out "if you move into a dead spot with the laptop you lose everything in CAMS and have to go to a live spot and reboot." It should be noted that this dead spot reported by the participant was not experienced during this test; experimenters attempted to reproduce the dead spot phenomena based upon the description given by the participant, but were unable to do so.

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Experimenters noted that two factors were likely to have influenced participant responses regarding wireless connectivity. First, it is possible that the additional logon required for network access in the mobile CAMS condition influenced perception of wireless connectivity, as this second logon was only necessary to connect to the wireless network. Second, experimenters noted that there was some difficulty with the logout process: when participants would shut down the mobile computer at the end of the test session, the network logoff process was often slow or even failed entirely. Such a problem could be associated with both network logon and wireless connectivity, and may well be reflected in the potential problems participants identified in both usability assessments.

After completing all tasks in both conditions, participants responded to questions regarding their preferences for access methods and interfaces. When asked which of the two methods individuals preferred, 5 of 8 participants indicated a preference for the stationary CAMS, 2 preferred the mobile CAMS, and 1 individual liked both equally well (Figure 8). Those who responded that they preferred the stationary CAMS provided reasons such as: the logon (and logoff) required in the mobile condition (which was in addition to the Windows and CAMS logon and logoff required in both conditions), the perceived higher reliability of the desktop connection, a preference for the traditional mouse over the stylus, difficulty with screen visibility on the mobile device, and a preference for access to air conditioning during maintenance documentation tasks. Both of the individuals who preferred the mobile CAMS did so because of the increased efficiency of access to the CAMS information while at the flightline. Finally, one individual pointed out "if all of the stationary terminals are in use you have your own personal terminal."

Overall Terminal Preference

Preferred Stationary   Equal   Preferred Mobile
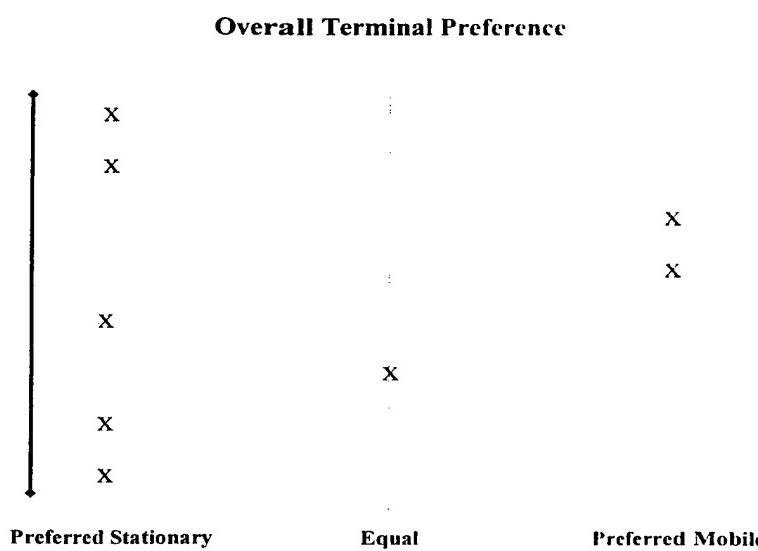
Figure 8. Participants' overall terminal preference.

Individuals were also asked the degree to which they agreed with the statement "The mobile CAMS terminal was less frustrating to use than the stationary CAMS terminal." Three individuals disagreed with this statement, and 5 participants responded that they neither agreed nor disagreed with this statement (Figure 9). All 3 of the individuals who disagreed with this statement commented that this was, at least in part, a reflection of logon difficulties that they experienced in the mobile CAMS condition. Participants in both the stationary and mobile CAMS conditions experienced the standard CAMS logon difficulties; however, participants in the mobile CAMS condition experienced difficulty with the network logon as well.

Frustration Level

| Strongly Agree | Agree | Neither Agree Nor Disagree | Disagree | Strongly Disagree |

Mobile CAMS system is less frustrating than the stationary CAMS system
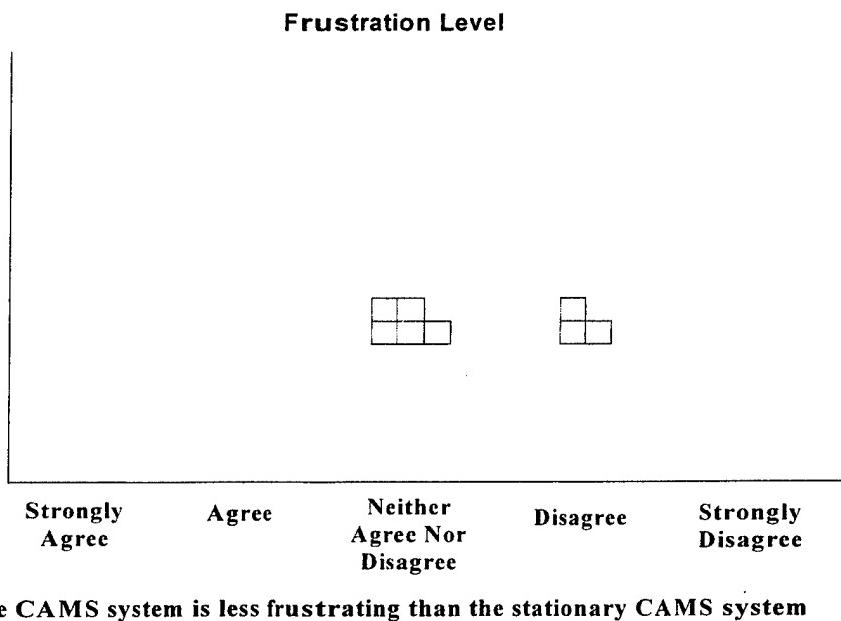
Figure 9. Participants' comparison of frustration in the stationary and mobile CAMS conditions.

Finally, individuals indicated their preference between the CAMS GUI and the CAMS Green Screen interface (Figure 10). Six participants indicated that they preferred the CAMS GUI (used in this study in both the stationary and mobile conditions), and two participants preferred the CAMS Green Screen interface. Both individuals who preferred the CAMS Green Screen interface did so because it is "much faster" than the GUI, and that it is "not as susceptible to Windows based crashes." As a Windows interface that runs on a Windows based computer, the CAMS GUI is affected by any Windows based errors or crashes; this is in contrast to the CAMS Green Screens (a DOS-like program), perceived by participants as less affected by any problems within the Windows system.

Interface Preference

| Preferred CAMS Green Screen | Equal | Preferred CAMS GUI |
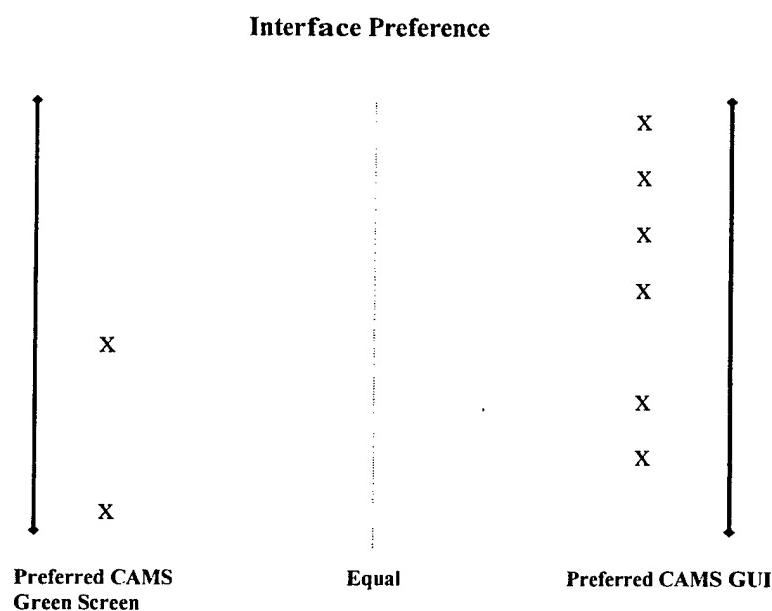
Figure 10. Participants' interface preference.

Those who preferred the CAMS GUI indicated that they liked the drop-down menus (particularly if the drop-downs can be made "faster and more reliable"), and that they liked the mobility associated with the GUI (in that any Windows based network connected computer can access it). Additionally, one participant stated that, "once you learn the GUI it has more benefits and uses." Whereas the CAMS Green Screen interface requires that the user recall or look up necessary information, the CAMS GUI provides cues in the form of drop-down lists to assist the user with appropriately populating the information.

These subjective findings are consistent with the hypothesis that the CAMS GUI is an improvement over the CAMS Green Screen interface. To further investigate this hypothesis, a *preliminary* empirical analysis was performed comparing the time required to complete the open job documentation task using both of these interfaces. CAMS GUI conditions were represented in the analysis of the stationary and mobile conditions for opening a job in this current study. Data for the CAMS Green Screen condition was taken from data collected during a similar study conducted at Hurlburt Field, the POMX Hurlburt Initial Structured Study (Gorman, Donahoo, Quill, Jernigan & Goddard). This preliminary evaluation indicates a potential significant

difference between the CAMS GUI and the CAMS Green Screen interface. The POMX Hurlburt Initial Structured Study (Gorman et al.) gathered baseline time data where participants completed the open job documentation task using the CAMS Green Screen interface; this was fundamentally the same task as the open job documentation task in the present study at Nellis AFB. Twelve participants took part in the Hurlburt study; data was gathered for eight participants in the present study at Nellis. Due to unequal n in these studies, an independent samples t-test with equal variance was calculated for the open job task in the stationary and mobile CAMS GUI conditions at Nellis AFB, and the stationary CAMS Green Screen interface condition at Hurlburt Field. Figure 11 reflects the average task times compared in this preliminary evaluation.
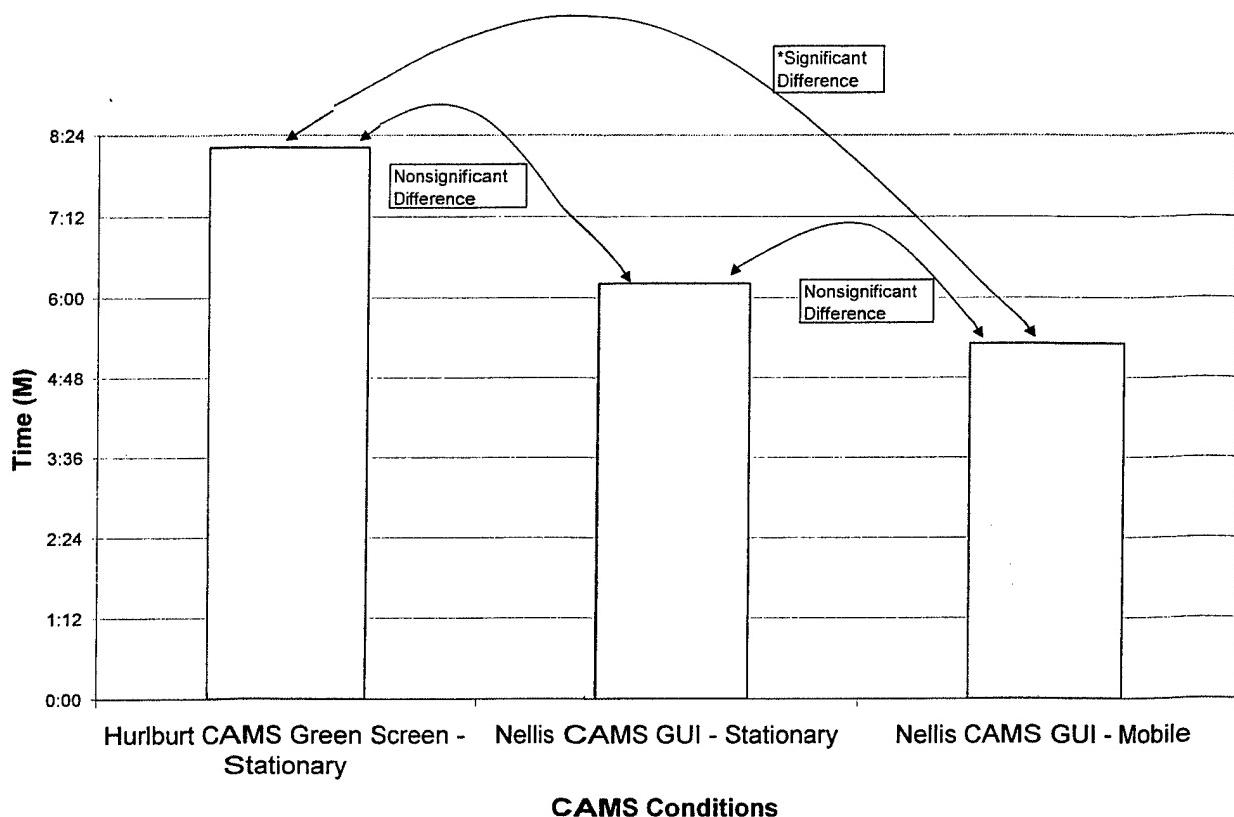
Figure 11. Average time of open job documentation tasks across CAMS systems.

Using this method, the open job documentation task using the mobile CAMS GUI was significantly faster than the open job task using the CAMS Green Screen interface on a stationary desktop [t (18) = 2.529, p < .05]. The mobile CAMS GUI condition showed an average of 0:05:19 to complete the open job task, while the stationary CAMS Green Screen interface condition showed an average of 0:08:13 to complete the same task.

There was no significance when comparing the open job documentation task in the stationary CAMS GUI condition to the open job task using the CAMS Green Screen interface on a stationary desktop [t (18) = 1.507, p > .05]. The stationary CAMS GUI condition showed an average of 0:06:13 to complete the open job task, while the stationary CAMS Green Screen

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interface condition showed an average of 0:08:13 to complete the same task. Analysis of these findings indicates that there might be a real advantage to using the mobile CAMS GUI over the stationary CAMS Green Screen interface. Visual inspection of the means indicates that there is some benefit gained from the use of the CAMS GUI; however, this benefit is not a significant one, as is illustrated by the lack of statistical significance between the CAMS Green Screen and the stationary CAMS GUI mean task times. Yet when combined with mobile computing, the CAMS GUI does show potential significant improvement. It is hypothesized that the direct access method allowed by the touch screen and stylus, when combined with the CAMS GUI, promotes enough of an improvement over the standard, indirect point-and-click mouse access method to account for the significant difference between the mobile CAMS GUI and stationary CAMS Green Screen interface conditions.

As shown in the results of the current study, the t-test showed no significance in the difference between the stationary and mobile CAMS GUI conditions. These results are discussed in the Objective Data section of this report.

Interestingly, this preliminary analysis showed a compelling loss in significance when time to sign-on to the network was incorporated in the task time in the mobile CAMS GUI condition. The t-test revealed that the open job task in the mobile CAMS GUI condition with network sign-on time was no longer significant as compared to the open job task using the stationary CAMS Green Screen interface [t (18) = 1.411, p > .05]. When sign-on time was included, the mobile CAMS GUI showed an average time of 0:10:02 to complete the open job task, while the stationary CAMS Green Screen interface showed an average time of 0:08:13 to complete the same task (see Figure 12). That is, the advantage gained over the stationary CAMS Green Screen interface by the mobile CAMS GUI is lost when time to sign-on to the network is included in the calculation.
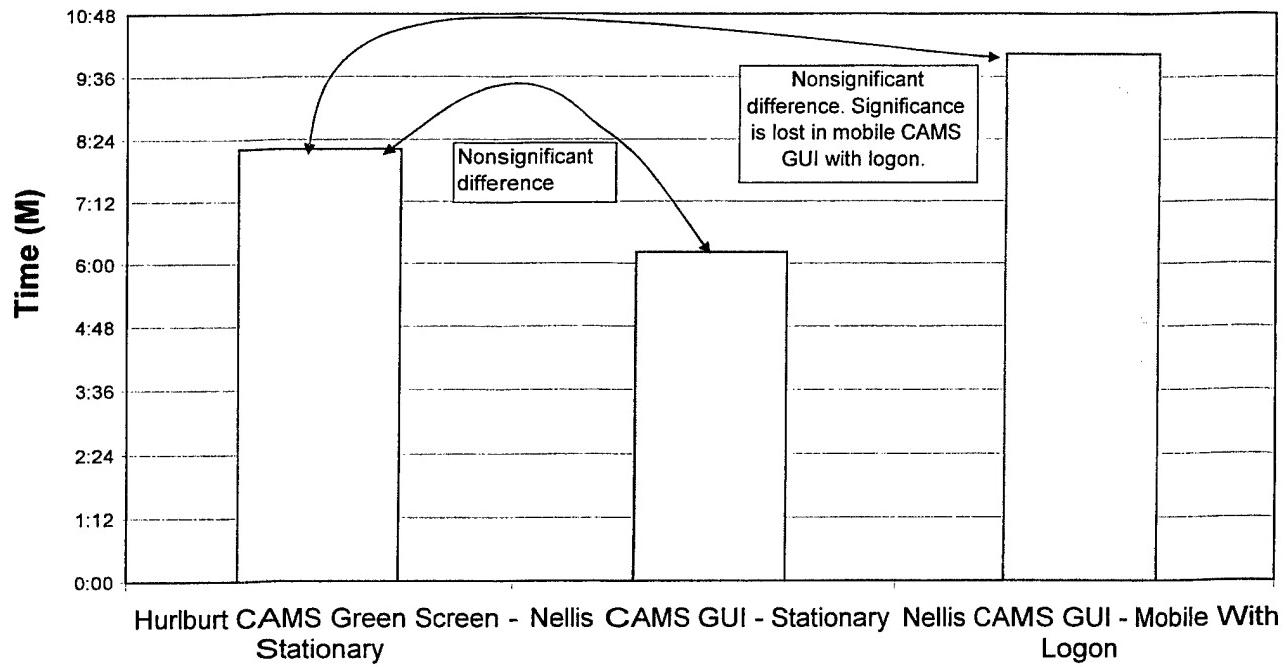
Figure 12. Average time of open job documentation tasks across CAMS systems with mobile logon.

It is important to note that this comparison of the CAMS GUI and CAMS Green Screen interface is a preliminary analysis. Such an initial evaluation was completed for discussion purposes, and does not have enough statistical power to be considered valid without further testing. For validity when comparing the performance times for task completion between the CAMS GUI and the CAMS Green Screen interface, it is important to control factors such as the following: subject number and experience; hardware configuration; locations; task requirements; network considerations; and aircraft being maintained. This preliminary CAMS GUI to CAMS Green Screen interface comparison is in addition to the primary purpose of this study which was to compare the mobile CAMS to the stationary CAMS. While limited in its validity, this preliminary analysis does pose some intriguing research questions which should be considered for future research efforts, especially with regard to the potential need for improvements to logon procedures.

4.2 Objective Results

In this study, participants first completed various maintenance documentation tasks in a baseline condition, a condition that replicated the manner in which the maintenance documentation is usually completed (i.e., stationary CAMS). Then participants completed the identical documentation tasks (i.e., open job, list open jobs, and close job) in the mobile CAMS condition. Start and stop times were recorded for each of these tasks. The time required to complete each task in each condition was then compared for each subject.

Stationary and mobile maintenance documentation task times were evaluated across eight different comparisons. These eight comparisons are derived from analysis that balances exclusion and inclusion of 1) travel time and 2) Windows and network sign-on times for completion of the maintenance documentation tasks (i.e., open job, list open jobs, and close job). Refer to Table 1 for a description of these conditions.

Table 1. Definition of Comparisons of Task Times

Comparison 1	Open Job Stationary (with travel) vs. Open Job Mobile
Comparison 2	Open Job Stationary (without travel) vs. Open Job Mobile
Comparison 3	Open Job Stationary (with travel and sign-on) vs. Open Job Mobile (with sign-on)
Comparison 4	Open Job Stationary (without travel and with sign-on) vs. Open Job Mobile (with sign-on)
Comparison 5	List Jobs Stationary (with travel) vs. List Jobs Mobile
Comparison 6	List Jobs Stationary (without travel) vs. List Jobs Mobile
Comparison 7	Close Job Stationary (with travel) vs. Close Job Mobile
Comparison 8	Close Job Stationary (without travel) vs. Close Job Mobile

Consideration was given to travel time required when accessing the stationary CAMS terminal. The primary difference between the mobile and stationary conditions is the point of access; therefore, travel time was incorporated into each discrete comparison. In the open job and list open jobs tasks, twice the average travel time of the maintainer was added to the participant's overall task time to reflect the required travel from the aircraft to access the CAMS terminal, and to reflect the required travel back to the aircraft to continue the maintenance or aircraft 781 forms documentation. In the close job task, the average travel time was added in once to reflect the maintainer's return from the aircraft to the stationary terminal, where the job would be closed in CAMS.

Conversely, consideration was given to sign-on time required for the mobile device. Both the stationary and mobile CAMS conditions required that the users sign-on to both

Windows and CAMS. The Windows sign-on time recorded in the stationary and mobile CAMS conditions reflected the entirety of the time it took for the user to activate and sign-on to the machine. As the stationary CAMS terminals were left on at all times, the Windows sign-on time for this condition simply reflected the time it took the user to unlock and sign-on to the workstation. On the other hand, participants were required to power on the laptop in the mobile CAMS condition: start up time was included in the total Windows sign-on time required in this condition. Furthermore, while the Windows sign-on served also to sign the user on to the network in the stationary CAMS condition, the mobile CAMS condition required that the user input an additional logon and password for network sign-on. It is anticipated that maintainers would sign-on to the device for their initial access, and remain signed on to the device for the duration of their continuous maintenance activities. For this reason, both Windows and network sign-on times have been included only with the initial open job task.

Finally, while it was assumed that maintainers would sign-on to the mobile device for their initial access and remain signed-on for the duration of their continuous maintenance activities, some consideration was given to the most appropriate representation of the sign-on process in the stationary CAMS condition. Best practices assume that a maintainer will immediately update CAMS anytime the status of an aircraft changes (e.g., opening a job to indicate that an aircraft is broken, or closing a job to indicate that the aircraft maintenance has been completed); however, it is not uncommon for technicians to access the CAMS database only a few times through their shift, and update all information at that time. This would involve, then, a single Windows logon for several maintenance documentation tasks (e.g., open jobs, close jobs) in the CAMS database. For the purposes of time comparison, this more efficient (although not more effective) approach was assumed. Windows logon times were only included in specified open job task comparisons. It should be noted that the list open jobs task would likely be completed in conjunction with another task, such as after opening or closing a job, and so the only task in this study that may involve additional time in a 'best practice' scenario would be the close job task.

### 4.2.1 Comparison 1: Open Job Stationary (with travel) vs. Open Job Mobile

Comparison 1 contrasts times for both stationary and mobile open job documentation tasks, including travel time. In this comparison, it is assumed that the maintainer would begin the inspection task at the aircraft. When CAMS access is required, the mobile CAMS access condition would allow the maintainer to remain at the aircraft, connecting to the CAMS database via remote frequency; the stationary CAMS desktop condition assumes that the maintainer would travel to the CAMS desktop from the aircraft to input information about the job and receive the appropriate information (i.e., Job Control Number, or JCN), and return to the aircraft to complete the inspection task and aircraft 781 forms documentation.

Statistical analysis of the time data for Comparison 1 shows that the mobile CAMS condition yields significant improvements over the stationary CAMS condition. This was explored using a dependant samples t-test conducted on the total task time for the open job documentation task in the stationary and mobile CAMS conditions.

To include travel times in the calculation, experimenters recorded the time required for each maintainer to travel from the CAMS terminals to the nearest aircraft parking location. This time was recorded twice for every participant, and these times were averaged to determine a

subject's travel time to include for calculations in this study. To portray a best case scenario, travel times to the nearest aircraft parking location were used.

As hypothesized, the time required to complete the documentation task in the mobile CAMS condition was significantly less than the time required in the stationary CAMS condition when travel time was included in the stationary condition [t (7) = 3.747, p<.05]. The mobile condition showed the average of 0:05:19 to complete the open job documentation task. The stationary condition showed an average of 0:10:38 to complete the open job task when travel to and from the aircraft to interact with the stationary system was included in the calculation. Figure 13 shows a comparison of average mobile and stationary task times in the open job comparison, both with and without travel times.
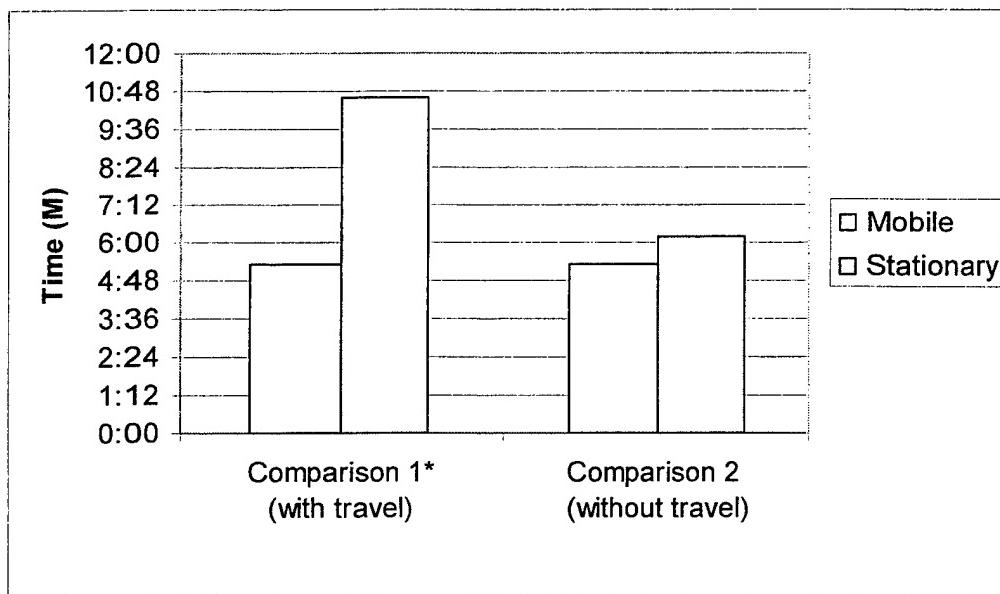
*p < .05.

Figure 13. Open job comparison of mobile and stationary task times with and without travel.

4.2.2 Comparison 2: Open Job Stationary (without travel) vs. Open Job Mobile

Comparison 2 contrasts task times for both stationary and mobile open job documentation tasks; this comparison does not include travel time or time required to sign-on to the system. For this comparison, only the actual times to complete the documentation task were evaluated. This excluded the time required for the maintainer to travel from the aircraft to the CAMS terminal, and the time required to return to the aircraft after receiving a response from the CAMS system. Furthermore, it excluded the time required for the initial wireless network sign-on in the mobile CAMS condition.

A dependent samples t-test indicated that the time required to complete the documentation task in the mobile condition did not significantly differ from the time required to complete the documentation task in the stationary condition [t (7) = 0.611, p>.05]. In the mobile condition, participants spent an average of 0:05:19 completing the open job documentation task, while in the stationary condition participants spent an average of 0:06:13 completing the open job task. These results are shown in Figure 13. This figure shows that time savings are realized

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through saved travel. Statistically significant differences in time required for performance of the documentation task itself were not found.

4.2.3 Comparison 3: Open Job Stationary (with travel and sign-on) vs. Open Job Mobile (with sign-on)

Comparison 3 contrasts task times for both stationary and mobile open job documentation tasks, including travel time in the stationary condition, and adding to both conditions the time required to sign-on to Windows and the wired or wireless network. Including travel time with this task renders the most realistic representation of the stationary CAMS condition; as well, this comparison considers additional time the maintainer currently requires to sign-on to each mobile device. This sign-on time includes a single logon in the stationary condition that signs the user into Windows as well as the wired network; in the mobile condition, this sign-on time included two logons serving to sign the user onto Windows and the wireless network, respectively. In this study, Windows and network start-up times were recorded with the open job documentation task; during actual maintenance activities, it is likely that maintainers will initiate the start up sequence on the mobile device for the initial use and will leave the device on for the duration of their maintenance inspection and documentation tasks. Note that Windows and network sign-on times were incorporated as an additional variable in both conditions in comparisons 3 and 4.

Statistical analysis of this time data shows that there was no significant difference between the average time of the stationary condition and the average time of the mobile condition in the open job documentation task where both travel and Windows and network sign-on were included in the relevant conditions. This was explored using a dependant samples t-test conducted on the total task time (including travel and Windows and network sign-ons) for the open job documentation task in the stationary and mobile CAMS conditions.

In this comparison, the time required to complete the task in the mobile condition did not significantly differ from the time required to complete the task in the stationary condition [t (6) = 1.206, p>.05]. The mobile condition showed the average time of 0:10:02 to complete the open job documentation task. The stationary condition showed an average of 0:11:11 to complete the open job task when travel to and from the aircraft to interact with the CAMS system was included in the calculation. Figure 14 shows a comparison of average mobile and stationary task times for the open job task where the time for Windows and network sign-on is included in the stationary and mobile CAMS data.

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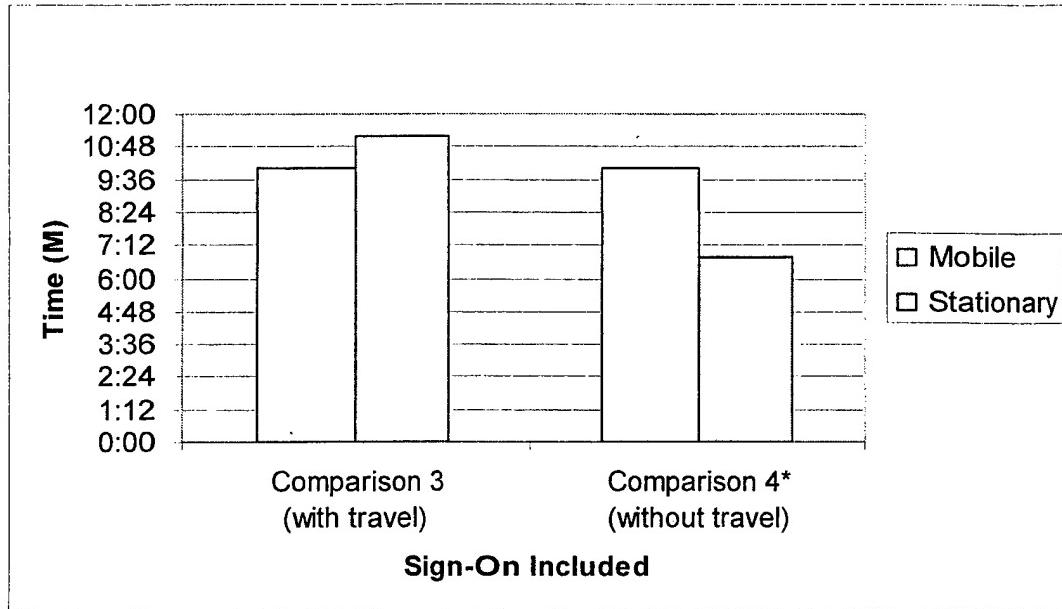
Figure 14. Open job comparison of mobile and stationary task times with and without travel where Windows and network sign-on are included.

4.2.4 Comparison 4: Open Job Stationary (without travel and with sign-on) vs. Open Job Mobile (with sign-on)

Comparison 4 contrasts task times for both stationary and mobile open job documentation tasks where travel time is not included, but time required in the stationary and mobile CAMS conditions to sign-on to Windows and the wired or wireless network is included. This comparison is included for completeness.

Statistical analysis of the time data in this comparison shows that the average time for the stationary condition was significantly lower than the average time for the mobile condition. This was explored using a dependant samples t-test conducted on the total task time for the open job documentation task in the stationary and mobile CAMS conditions. The time required to complete the task in the mobile condition was significantly greater than the time required in the stationary condition when sign-on time was considered in both conditions and travel time was not incorporated into the stationary condition [$t (6) = 3.378$, $p<.05$]. The mobile condition with sign-on included showed the average of 0:10:02 to complete the open job task. The stationary condition, with sign-on, showed an average of 0:06:48 to complete the open job documentation task when travel to and from the aircraft to interact with the stationary system was not included in the calculation. Figure 14 illustrates the average mobile and stationary task times for this comparison.

4.2.5 Comparison 5: List Jobs Stationary (with travel) vs. List Jobs Mobile

Comparison 5 contrasts task times for both stationary and mobile listing of open jobs where travel time is included in the stationary CAMS condition. This travel time reflects the time the maintainer would spend traveling from the aircraft indoors to gain access to the stationary CAMS system to list the open jobs, as well as the time the maintainer would spend returning to the aircraft with that list. Again, to include travel times in the calculation, experimenters recorded the time required for each maintainer to travel from the CAMS terminals to the nearest aircraft parking location. This time was recorded twice for every participant, and these times were averaged to determine a subject's travel time to include for calculations in this study. Twice that average (to indicate travel to and from the CAMS terminal) is added to the list open jobs task time in the stationary CAMS condition for this comparison.

As hypothesized, the time required to complete the task in the mobile condition was significantly less than the time required in the stationary condition when travel time was included [$t(7) = 10.821$, $p<.05$]. The mobile condition showed the average of 0:01:50 to complete the list open jobs task. The stationary condition showed an average of 0:06:22 to complete the list open jobs task when travel to and from the aircraft to interact with the stationary system was included in the calculation. Figure 15 shows a comparison of average mobile and stationary task times for this comparison.
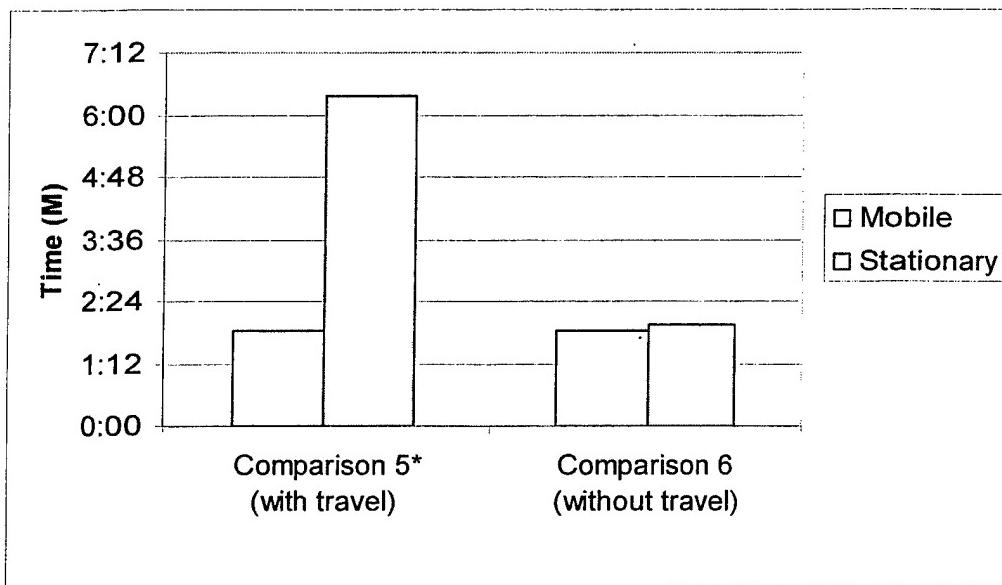
*$p < .05$.

Figure 15. List open jobs comparison of mobile and stationary task times with and without travel.

4.2.6 Comparison 6: List Jobs Stationary (without travel) vs. List Jobs Mobile

Comparison 6 contrasts task time for both stationary and mobile listing of open jobs where travel time is not included in the stationary CAMS condition. That is, this comparison reflects time that the user was actually interacting with CAMS over the connected and wireless networks, and does not consider time the maintainer would have spent gaining access to a CAMS terminal.

As hypothesized, statistical analysis of the time data in this comparison shows that there was no significant difference between the average time of the mobile condition and the average time of the stationary condition for the listing of open jobs task when travel was not included [t(7) = 0.249, p>.05]. This was explored using a dependant samples t-test conducted on the total task time for the list open jobs task in the stationary and mobile CAMS conditions. The mobile condition showed the average of 0:01:50 to complete the list open jobs task. The stationary condition showed an average of 0:01:57 to complete the list open jobs task when travel to and from the aircraft to interact with the CAMS system was not included in the calculation. Figure 15 illustrates average mobile and stationary CAMS task times, both with and without travel. Again, this figure shows that time differences between platforms are due to travel.

4.2.7 Comparison 7: Close Job Stationary (with travel) vs. Close Job Mobile

Comparison 7 contrasts task times for both stationary and mobile close job documentation tasks, and includes travel time required to close the maintenance job within CAMS in the stationary condition. In this comparison, the participant's average travel time was added to his CAMS access time only once; this reflects the maintainer's action of returning to the stationary CAMS terminal from the aircraft to close the job.

Statistical analysis of the time data in this comparison shows that the mobile condition yields significant time improvements over the stationary condition for the close job task where travel is considered. This was explored using a dependant samples t-test conducted on the total task time for the close job task in the stationary and mobile CAMS conditions. The time required to complete the task in the mobile condition was significantly less than the time required in the stationary condition when travel was included [t (7) = 4.630, p<.01]. The mobile condition showed the average time of 0:02:47 to complete the close job task. The stationary condition showed an average of 0:05:31 to complete the close job task when travel from the aircraft to interact with the CAMS system was included in the calculation. Figure 16 illustrates the average mobile and stationary task times in this comparison.
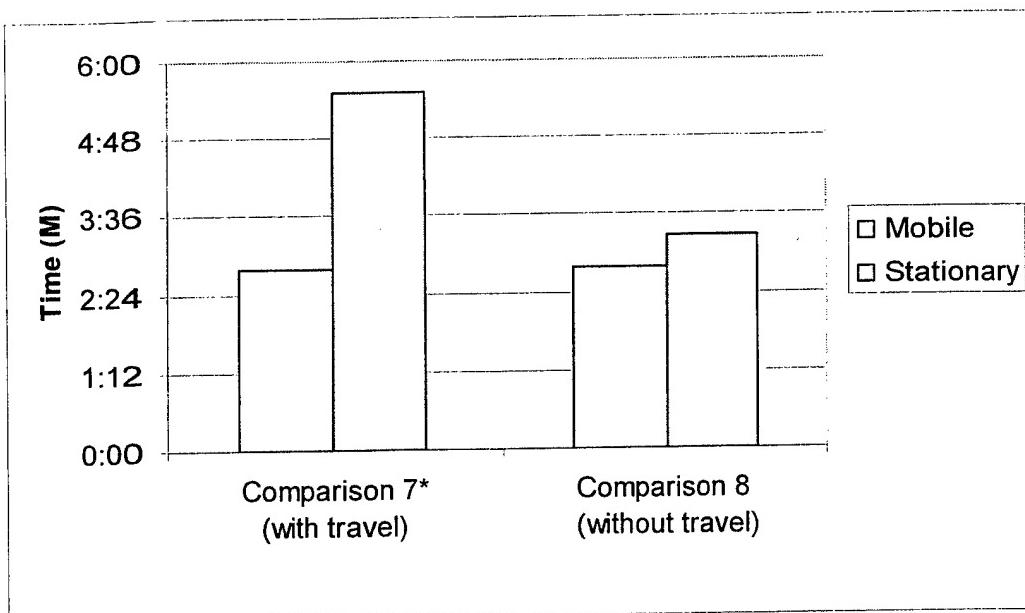
Figure 16. Close job comparison of mobile and stationary task times with and without travel.

4.2.8 Comparison 8: Close Job Stationary (without travel) vs. Close Job Mobile

Comparison 8 contrasts task times for both stationary and mobile close job documentation tasks where travel time is not included in the stationary CAMS condition. That is, this condition reflects time that the user was actually interacting with the CAMS system over the connected and wireless networks, and does not consider time the maintainer would have spent gaining access to a CAMS terminal.

Again as hypothesized, the time required to complete the task in the mobile condition did not significantly differ from the time required to complete the task in the stationary condition [t (7) = .830, p>.05]. The mobile condition showed the average of 0:02:47 to complete the close job task. The stationary condition showed an average of 0:03:16 to complete the close job task when travel from the aircraft to interact with the stationary system was not included in the calculation. Figure 16 illustrates average mobile and stationary task times in this comparison. Again, the addition of travel time is the significant difference in the close job documentation tasks on the CAMS platforms tested.

5 Discussion

The purpose of this study was to provide subjective and objective data, comparing the usability of the mobile CAMS device to the current stationary CAMS system for maintenance documentation tasks.

Overall Time Savings

It was hypothesized that, due to elimination of travel, the mobile CAMS system would allow for significant improvements in the time required to complete maintenance at the aircraft, as necessary documentation was completed *at the point of maintenance*. For example, the current method for completing the open job task requires that the maintainer, upon finding a problem, complete paper documentation at the aircraft, then proceed indoors in order to use the CAMS system. The maintainer signs in to the CAMS terminal, opens the maintenance job, fills out the necessary fields within the system and sends the job, and then waits for a response from the CAMS system with a Job Control Number (JCN). At this point, the maintainer signs out of the CAMS system, returns to the aircraft, and documents the JCN in the aircraft's paper maintenance forms. Using the mobile CAMS system, maintainers can access information in the CAMS database using a laptop connected to the wireless network, and can complete the steps necessary for the documentation tasks while at the point of maintenance.

It should be noted that the stationary CAMS condition in this study was configured to represent the best possible scenario for travel. Time data was collected while walking, as quickly as possible, to and from the nearest aircraft parking location. Given that convenient location of aircraft is fairly infrequent, it is reasonable to expect that travel time will be at least equivalent to (and probably greater than) the travel time included in this study. Also, in ordinary maintenance activities involving the stationary CAMS system, the maintainer often does not enter data into CAMS until the end of his or her shift. Thus, maintenance data in CAMS may not actually be updated for up to eight hours. In such a case, the maintenance information at the aircraft will not be current until after the maintainer has received responses from the CAMS system and updated the documentation at the aircraft. On the other hand, with the mobile CAMS system the database information and documentation at the aircraft are more likely to be current, as maintainers can access CAMS to update it as soon as maintenance is completed.

As hypothesized, this study did show significant timesavings in the mobile CAMS condition as compared with the stationary CAMS condition when travel was considered (Comparisons 1, 5, & 7).

Knowledge transfer

When travel was not included in the time measurements, there were no significant differences between the open job, list open jobs, and close job documentation tasks (Comparisons 2, 6, & 8). This would suggest that the mobile CAMS system is comparable to the stationary CAMS system in these tasks, as would be expected since the interfaces are the same. The lack of difference found between these conditions is important. Users do not have to learn two different interfaces (one for the mobile and one for the stationary CAMS access); thus, learning to use one translates to equivalent performance on both.

Logon issues

To account for logon activities, this study included Windows sign-on time in the open job task in both the stationary and mobile CAMS conditions. This assumes that the mobile device will be left on for the duration of the maintenance activities, and that the maintainer will logon to the stationary CAMS system only one time to complete the open and close job tasks. While time to complete the close job task did not significantly differ between the stationary and mobile CAMS conditions, this calculation was performed assuming that the maintainer did not have to login to Windows before completing the close job documentation task.

It is interesting that when logon and travel time were included, there were no significant differences in overall documentation task times. However, when the open job task comparison did not include travel time but included the time required to sign-on to the network, the mobile condition took significantly longer. This difference due to logon time is validated by the subjective feedback provided by participants that indicated that network logon and wireless connectivity were potential problems.

There are a number of factors that could have contributed to the less favorable performance (and thus, user perception) of the network logon for the mobile device. First, the stationary CAMS condition consisted of a Windows logon only, whereas the mobile condition required both a Windows and a network logon. Not only did this add an additional step to the process, but the network logon in the mobile CAMS condition required an additional password that was often not easily recalled by users. Some maintainers simply did not recall their password, either because they did not login to the wireless network on a regular basis, or because they had not logged into the wireless network for such a length of time that they required new passwords. The CAMS logon, on the other hand, was rated by individuals as acceptable across both conditions. These findings indicate that *difficulties with the logon process need to be addressed.* A synchronized logon for Windows and the wireless network should be required.

Wireless network delays

In addition to the objective results, subjective results suggest that interacting with the CAMS database via the wireless network may have exacerbated some issues. The additional network logon, discussed above, was defined as a potential problem. The drop-down menus — that were a potential problem in both conditions – were more slowly populated in the mobile condition; in both conditions, the drop-down menus took as long as 60 seconds to populate. Some participants would simply cancel out of the drop-down menu and enter a code from memory rather than wait for the system to return the necessary data. (Of course, this strategy is only effective if the individual recalled the number or code that they were looking for in CAMS.) Experimenters did note that, although participants experienced lengthy waits while the drop-down menus populated in both conditions, those in the mobile condition often experienced longer and more variable delays, most likely due to the variance of traffic across the wireless network.

Another finding from the subjective evaluation revealed that maintainers frequently experienced a long logoff time in the mobile condition (at times, this logoff process simply did not complete). In some cases, it was unclear whether the individual was logged out or not. This was due in part to the process required for the system to recognize a logoff request, and was aggravated by the lag time of the wireless connection. Overall, the logoff process created difficulties for other individuals upon logging into the system, and thus perpetuated any

frustration experienced with the additional logon and ambiguous logoff required in the mobile condition.

Printing

Interaction with the CAMS database over a wireless network promotes the potential for confusion about printing processes and locations. User comments regarding the potential problem of printing in the mobile condition related primarily to the need for coordination and set-up to ensure proper printer settings are available for each user.

User perceptions

Based on other user feedback and experimenter observations, it is likely that the sometimes lengthy response time of the CAMS system – in the drop-down menus, and elsewhere – lends to frustration with the system, especially in the mobile condition. Five of eight participants found the two systems to be equally frustrating, indicating some ambivalence toward both systems. However, the remaining three participants determined that the mobile CAMS system was more frustrating. Given the additional difficulties incurred with gaining and terminating access to the wireless network, this response is not unexpected.

Similarly, the majority of participants preferred the stationary CAMS system to the mobile CAMS system. The reasons provided by participants include, most notably, the additional logon process in the mobile condition, as well as the higher perceived reliability of the stationary terminals, the preference for the traditional mouse over the stylus, and the need (somewhat unique to Nellis AFB) to get inside periodically and away from the heat of the flightline. One final preference comparison was made between the current CAMS GUI and the recently replaced CAMS Green Screen interface. The majority of participants preferred the CAMS GUI, which "has more benefits and uses." It should be noted that, while maintainers may prefer the CAMS GUI over the CAMS Green Screen interface, any timesavings offered by the CAMS GUI (specifically, the mobile CAMS GUI) may be mitigated by unresolved difficulties with the wireless network sign-on process.

Conclusions

In conclusion, the mobile CAMS condition was faster than the stationary CAMS condition when necessary travel time was included. However, the mobile unit had an additional network logon that hindered the participants from completing the open job documentation task as quickly as anticipated, as well as a longer lag time due to the wireless connectivity. Subjective data revealed that the drop-down menus were potential problems in both the stationary and mobile CAMS conditions.

The results of this study indicate that there are benefits to having both the mobile and stationary systems in use. The mobile CAMS system allows the aircraft maintenance job documentation data to be updated in the timeliest fashion, at the point of maintenance. This eliminates travel time, and increases the accuracy and currency of the data in the CAMS database. In addition, with the mobile CAMS system, maintainers can reference the data they need while at the aircraft, which may greatly reduce the need for tasks similar to the print open jobs task. As one maintainer suggested, the availability of both systems resolves the ever-present concern of system access, noting that, at the very least, "if all the stationary terminals are in use you have your own personal terminal." On the other hand, maintainers are currently more familiar and comfortable with the stationary system, and this system also allows relief from

oppressive or inclement weather. The recently implemented CAMS GUI is already an improvement over the CAMS Green Screen interface; however, results indicate that potential problems exist with the drop-down menus. In their current forms, the use of both systems may be the most beneficial option, offering the convenience and efficiency of mobile access as well as the stability and familiarity of the stationary system.

6 Recommendations

The results of this study indicate that there are considerable gains to be made in the efficiency of maintenance documentation tasks and, thus, maintenance tasks overall. Potential gains include time savings in data entry and retrieval, error reduction due to reduced memory load, and more timely entry of data into CAMS.

For this study, the reported time savings where necessary travel time was incorporated into task time were significant. Minutes saved each time a job is opened or closed enable a more efficient and effective maintainer. Furthermore, average travel time was determined based on the location of the nearest aircraft parking location. As travel time will vary widely based upon the flightline size of various installations, it should be noted that flightline size should clearly be considered when estimating the potential time savings a unit might gain by incorporating mobile devices that might be utilized to interact with MDC systems from the point of maintenance.

The following recommendations are a result of this study:

- **Allow both stationary and mobile CAMS access devices to be put to use.** While the stationary system has proven its viability and provides the technician with relief from unfavorable weather conditions, the mobile device provides more access to information while at the aircraft, and significantly improves the timeliness of data.

- **Improve the speed and usability of drop-down menus.** The intent of the drop-down menus is to provide, within the GUI, any and all relevant codes or characters that may be used to populate a field. This should, then, allow the maintainer to navigate through the CAMS GUI without requiring additional reference manuals. However, the number of values returned is often so great that population of these windows takes an inordinate amount of time; some maintainers simply choose not to use this resource because of this (and are forced to recall the information from memory or find the book to look it up), and others endure the often frustrating wait. The process of populating the drop-down menus should be reassessed to determine if the values could be accessed without such an extensive, time-consuming database search. In addition. the current drop-down menus do not function in a manner consistent with the expectations of a standard Windows user. When an individual selects a drop-down, he or she is not given a scrollable list that populates the field once a value is clicked upon. Instead. selection of a drop-down menu causes an additional window to open up. Users must search through this window for the desired value, choose it, and close the window. This process is more involved, and thus less acceptable, than the traditional Windows drop-down menu format.

- **Improve the mobile logon process.** In the stationary CAMS condition, users were required to input only one logon; this is because Windows and network logons were coordinated such that both processes were achieved with a single logon. This coordination was not in place for the mobile CAMS condition. and user feedback indicated that the frustration level was increased because of the complications with this additional step. The system should automatically provide a coordinated logon for each user.

- **Address difficulties with the wireless network.** Not only is there a perception that the wireless network is not as reliable (i.e., it has "dead spots"), but traffic over the wireless network is highly variable and can create more slow and frustrating interaction with the mobile CAMS system. It is likely that some of this frustration will be alleviated as technology improves.

- **Continue to look for technology improvements.** Continued consideration of the use of the CAMS GUI across multiple styles of mobile computing devices is recommended. While the mobile computer used in this study was state-of-the-art at the time, technology continues to evolve. In the current study, there was some concern that the device was not entirely sunlight readable, and some participants indicated a preference for use of the mouse over the touch screen and stylus of the laptop. Revels et al. explored maintainers' reactions to various suites of electronic devices, including a variety of access methods. One result of this study indicated that maintainers preferred use of a track ball mouse, or a stylus attached to the electronic device by a retractable tether. Future studies may explore the most appropriate input devices for maintainers entering data at the point of maintenance.

- **Configure printer for the user's location.** Ensure that printers are pre-configured for users so that they can easily select the appropriate printer for their location. This should not be accomplished as the user checks out the system, but should be an administrative function accomplished before users arrive to check out a device.

- **Rework the log-out procedure for the mobile device.** Allow the user to send a simple command, and then have the network (not the wireless network) log them out. Ease in accomplishing this task will reduce both the errors and frustration with the mobile device.

- **Keep the interface consistent between the mobile and stationary platforms.** The consistency of interface used will greatly affect how and when technicians use the device. If the same interface is available on each device, maintainers will be more likely to enter data at the point of maintenance. Ultimately, this will improve the timeliness of data.

- **Explore the improvement of the CAMS GUI over the CAMS Green Screen interface within a pool of unseasoned users.** Such a pool of users will more effectively reveal any advantages gained by the additional information provided within the CAMS GUI, and will likely offer the most unbiased comparison of these two methods of CAMS access.

This study represents an important first step in assessing the feasibility and potential benefits of the mobile CAMS system. Further refinement of this technology may realize more definitive improvements. Overall, findings from this study are promising and suggest important questions for future research.

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